BROWN-ROT, SCLEROTINIA CINEREA SCHROET.*

ITS APPEARANCE, CAUSE, AND CONTROL.

G. H. CUNNINGHAM, Biological Laboratory, Wellington.

BROWN-ROT is the most serious of all fungous diseases occurring on stone-fruits. With the exception of Central Otago, where, apparently, it is unknown, brown-rot is common throughout New Zealand, occurring on apricots, cherries, nectarines, peaches, and plums.

As a rule it does not infect apples and pears, but occasionally it is found on these hosts. In such cases infection occurs through insect punctures or other skin-injury, the spores in all probability being carried to these injuries by insects, such as bees. That these are not natural hosts of the fungus in question appears to be evidenced by the behaviour of apple and pear fruits which have been artificially inoculated with conidia. Brown-rot appears in the flesh as the result of inoculation, and gradually spreads until in time the whole fruit becomes infected, when it turns quite black, fruits at this stage somewhat resembling those infected with black-rot. Few or no tufts of conidia are produced on the surface of such fruits, the behaviour of the organism differing from that shown on stone-fruits, where inoculation is followed by rapid rot, and the appearance of tufts of conidia on the surface of the fruit within a short time (thirty-six to forty-eight hours) after infection (Fig. 2).

Brown-rot is common in Australia, certain parts of North America, and on the Continent of Europe, where it is widely distributed. In Europe a brown-rot on pome fruits (apples, pears, and quinces) is known, which is destructive to these hosts, but causes little or no damage to stone-fruits. In New Zealand this disease, caused by a related species of fungus, *Sclerotinia fructigena* Schroet., fortunately does not occur.

ECONOMIC IMPORTANCE.

Until the year 1915 brown-rot was of comparatively little moment in New Zealand, but in the spring of that year great damage was caused both to blossoms and fruit. Since that date brown-rot has become the most destructive disease with which the grower of stone-fruits in this country has to contend. It attacks blossoms, shoots, leaves, and fruits, causing the death of blossoms, formation of cankers on the shoots, perforations in the leaves, and rotting of fruits. The effects of the disease are not limited to the orchard, as fruit commonly becomes infected during transit, and opens up in the market in a badly rotted condition.

Although blossom-infection is not often recognized, this condition usually being attributed to some other agency such as frost injury,

* Synonyms: *Monilia cinerea* Schroet. Blossom-blight; brown-rot canker; peach-rot; ripe-rot; twig-blight.

it causes a serious loss, as the infected blossoms are killed outright, and in cases of severe infection a tree may fail to set any fruit. The damage does not cease with the death of the blossoms, as the mycelium of the fungus frequently grows through the pedicel of the blossom into the shoot to which it is attached, and there forms small cankers, which may continue to enlarge until the shoot becomes girdled and dies, thus destroying tissue which should be available as fruiting-wood for the following season.

Leaf-infection is followed by the appearance of small, brown, more or less circular dead areas, which may later fall away, leaving perforations in the leaf similar to those caused by shot-hole (Fig. 1). In extreme cases the leaves are killed outright, when they usually fall to the ground. When fruits become infected complete rotting follows within a few days, the entire crop being sometimes lost in cases of severe infection, as those familiar with the disease have only too often observed.

Transit infection causes considerable loss, not only because a percentage of the fruit reaches the market in an unsaleable condition, but because in a season when brown-rot is prevalent the buyer is prepared to pay only a low price for fruit that may rot before being sold. Moreover, in order to safeguard himself against losses in the handling of infected fruit he is forced to charge a correspondingly higher price for all sound fruit sold. Increased price has its effect on the market, as it limits the quantity of fruit sold to those few able to pay the high retail prices that are demanded.

Summing up, brown-rot may reduce the crop by destruction of blossoms and mature fruits, or affect the following season's crop by partial defoliation of the tree or killing of laterals and branches, while its non-control seriously reduces the commercial value of the crop by lowering the wholesale price, and, again, limits the development of the stone-fruit industry by raising the retail price to a level that restricts consumption.

APPEARANCE AND EFFECT ON THE HOSTS.

As a rule brown-rot first appears on the blossoms; but this stage, being governed in its occurrence by atmospheric conditions, may be absent, though a wet season following a cold winter is usually followed by blossom-infection, which may become so general that the greater part of the crop is lost. Infection may occur before the petals unfold, or shortly after they have opened, the period of infection extending from the beginning of September to the last week in October, according to the time of flowering of the variety. Following infection the blossoms die and turn brown, the mycelium of the fungus then growing through the pedicel and entering the shoots at the base of the bud, where it forms a small canker. During its formation gumming occurs, the gum exuding on to the surface of the shoots, where it tends to adhere to the dead blossom and hold it to the lateral, with the result that the dead blossoms do not fall but persist where they have been killed, often for several weeks. Blossom-infection may occur in another manner, through the mycelium of the fungus spreading from the young lateral up the pedicel to the blossom. In such a case it would appear that the lateral has first become infected, forming at the

FIG. 1. LEAF-INFECTION: CIRCULAR DEAD AREAS HAVE BEEN KILLED BY BROWN-ROT FUNGUS. NATURAL SIZE.

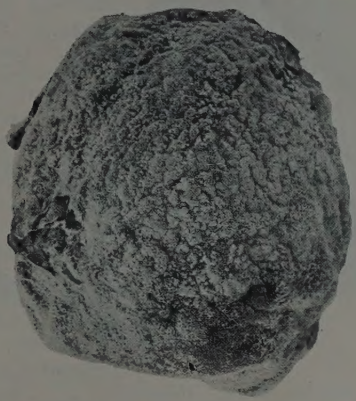

FIG. 2. FRUIT-INFECTION: MATURE PEACH-FRUIT COVERED WITH ASHY-GREY PUSTULES OF CONIDIA. NATURAL SIZE.

[*Photos by E. Bruce Levy.*

base of the bud a small canker from which the mycelium has spread to the blossom as described above. Following the formation of cankers on laterals the mycelium of the fungus may continue to extend until the whole shoot becomes girdled, when it rapidly wilts and dies. This condition is commoner at the time of the maturing of the fruit, and will be discussed more fully later. As a rule blossom-infection does not destroy all blossoms, but attacks a small percentage only. In exceptional cases, however, it has been known to kill outright all the blossoms.

Infection of the developing fruits may directly follow blossom-infection, but generally the disease does not manifest itself until about the time of maturity of the fruits. Fruit-infection first becomes noticeable from the presence on the epidermis of small, brown, more or less circular areas. These spots are not clearly defined in the early

stages from the healthy tissues, but as the rot progresses the outline becomes sharp, and about thirty hours after infection small, scattered, ashy-grey tufts of conidia appear upon the exterior of the infected areas. In from three to five days the fruit becomes discoloured and rotted throughout, the entire surface being covered with the numerous conidial tufts, which may at first be scattered but soon become so closely packed together that the whole fruit appears as if covered with an ashy-grey powder (Fig. 2).

The fungus may continue to grow down the fruit-pedicel into the lateral at the base of the bud, and form small cankers similar to those already discussed, from which it may extend along the shoot until it comes to a large branch. It may penetrate this and continue to develop until it ringbarks the branch, which suddenly wilts and dies. On such a branch gumming is conspicuous, but the most noticeable effect is the wilting and browning of the leaves, which remain on the tree after their death. Quite a large portion of the wood of a tree may be killed in this way, the destruction of branches, of course, lessening the following season's output. Moreover, cankers may persist in these branches for several seasons, and thus become an important source of infection each year.

FIG. 3. CONIDIAL PUSTULES. × 10.
[*Photo by E. Bruce Levy.*

After a time infected fruits become somewhat hard in texture and wrinkled in appearance. The tissues being permeated with the mycelium, the fruit is now known as a "mummy." If the mummy persists on the tree until the following spring the mycelium within it is capable of producing conidia (or more correctly chlamydospores) throughout the winter, and of acting as a source of infection the following season. In fact, the mummy is usually covered with these spores. Should the mummies fall to the ground the mycelium after a time undergoes a slight change, becoming darker in colour. In short, sclerotia* are formed, from which, at blossoming-period, fructifications of another kind may be produced. These are described in detail later.

LIFE-HISTORY OF THE CAUSATIVE ORGANISM.

Brown-rot is caused by *Sclerotinia cinerea* Schroet., a fungus having two spore forms (conidia and ascospores) in its cycle. For many years the fungus was known only from the conidial stage, which was named *Monilia cinerea* Bon. In 1902, however, J. B. S. Norton discovered the perfect or ascigerous stage growing from mummified plums

* Literally, closely woven masses of hyphæ which act as resting-organs to tide the fungus over an unfavourable period.

in an American orchard. Until a few years ago this fungus was considered to be the same as that occurring on pip-fruits, but recent work on the part of W. A. Matheny (1913) and J. S. Cooley (1914) has shown that the organism on stone-fruits is quite distinct.

The disease may first appear at blossoming-time, when the opening blossoms become infected. Infection may be due to (1) ascospores produced from mummies lying on the ground, (2) conidia produced from mummies hanging on the trees, or (3) conidia produced from mycelium overwintering in cankers on the laterals or branches. Whether infection is from ascospores or from conidia the method of attack is the same, for should the spores alight on the petals or other parts of the flower, and abundant moisture be present, they germinate and produce a germ-tube, which rapidly penetrates into and kills the tissues. Within a few days tufts of conidia may be produced on the petals, &c., of infected flowers, and they may also appear on the

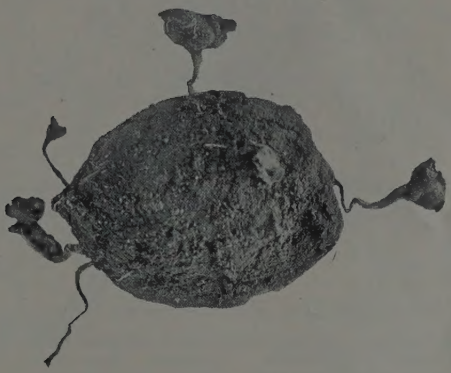

FIG. 4. APOTHECIA PRODUCED FROM SCLEROTIA CONTAINED WITHIN MUMMY OF FRUIT. NATURAL SIZE.

[*Photo by E. Bruce Levy.*

surface of the canker formed as the result of shoot-infection. Should they happen to be carried on to them conidia may in turn infect developing fruits in their vicinity. In an ordinary season, however, the disease does not again become prevalent until the fruits near maturity, though in a wet one fruit-infection may occur to a greater or less extent during the whole of the growing season.

As the fruits reach maturity the disease becomes noticeable, owing to the rapid manner in which they begin to rot. Infection at this stage may occur from conidia produced from mummies remaining on the tree, from conidia produced from cankers formed the previous season, or from conidia produced on blossoms and shoots as a result of blossom-infection. Ascospores, however, do not play a part in infection at this stage, as they are produced only at blossoming-time.

Whatever their origin, the conidia are carried on to the fruit by wind, insects, or even birds.*

Although infection most commonly takes place through wounds, it may occur wherever fruits are in contact (probably because moisture would be held at a point of contact for a longer period). In a wet season, however, infection may occur wherever the conidia happen to alight on the fruit. The conidia germinate in the presence of moisture

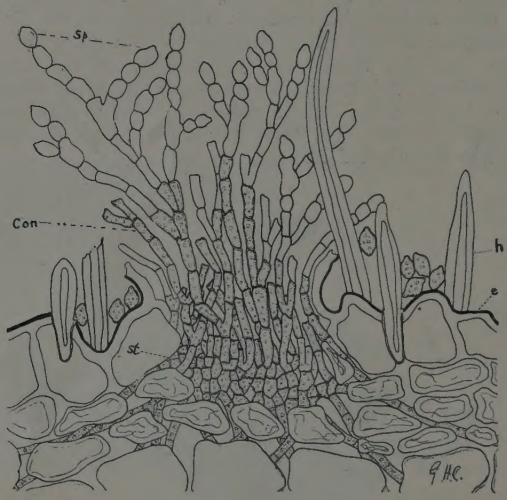

FIG. 5. SECTION THROUGH CONIDIAL PUSTULE ON FRUIT OF PEACH.

(*con*) Conidiophores; (*e*) epidermis (cuticle indicated by heavy line); (*h*) hair on epidermis of peach; (*sp*) conidia; (*st*) stroma. Note conidia lodged on surface between the surface hairs of the fruit. Camera lucida drawing. × 375.

[*Original.*

and produce a germ-tube (hypha), which penetrates the epidermis and enters the tissues, beneath which it quickly grows and branches until quite a number of hyphæ are developed. These grow between the cells, killing them as they advance by the secretion of certain toxic substances. A closely woven mass of hyphæ (stroma) is soon formed (Fig. 5, *st*), and from this is given off upright hyphæ (conidiophores) (Fig. 5, *con*), which push through the now dead epidermis (Fig. 5, *e*), where they appear on the surface as small thread-like tufts. From the conidiophores conidia are produced. These are at first in chains (Fig. 5, *sp*), owing to the rapid method in which they are formed, but

* Mr. J. C. Neill informs me that at Weraroa a small bird, locally known as "silver-eye" or "white-eye" (*Zosterops lateralis* Latham), is the cause of widespread brown-rot infection. With their beaks the birds commonly pierce infected fruits, and turn from these to healthy fruits, especially those showing colour, such as nectarines, which in turn they puncture, probably with a view to ascertaining whether they are edible.

as they are only lightly attached to one another they soon become separated (Fig. 6, *c*), and appear as an ashy-grey powder upon the surface (Fig. 3). Conidia may be produced within thirty-six hours after infection, and in about four days the fruit may be completely rotted, so rapidly does the fungus develop. The hyphæ from which the conidiophores are produced continue to grow within the tissues of the fruit until the whole becomes permeated.

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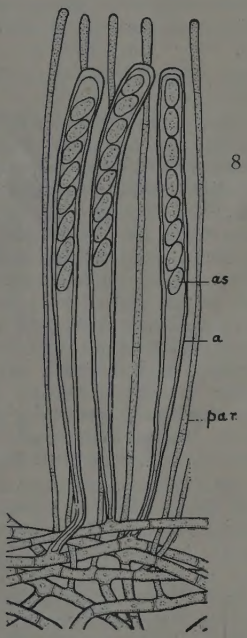

FIG. 6. CONIDIA. × 500.

(*a*) Chain of thin-walled conidia; (*b*) free conidia; (*c*) germinating conidium, germ-tube protruding from each end; (*d*) chain of chlamydospores. Generally on germinating these produce chains of conidia. [*Original.*

FIG. 7. APOTHECIA. NATURAL SIZE.

(*a*) Immature; (*b*) mature apothecium; (*c*) stalk; (*d*) section; (*e*) portion of mummy. [*Drawn from nature by E. H. Atkinson.*

FIG. 8. SECTION THROUGH HYMENIUM. × 500.

(*a*) Asci; (*as*) ascospores; (*par*) paraphyses. Camera lucida drawing. [*Original.*

Infected fruits may remain on the tree until the following season, or they may fall to the ground. Should they remain, the mycelium may continue to produce conidia throughout the season. Conidia produced from these mummies during the winter months are slightly thicker-walled than those produced during the growing-period, and

are capable of remaining viable for several months, thus differing from summer conidia, which remain viable for quite a short time—six weeks or even less. These winter conidia are termed "chlamydospores" (Fig. 6, *b*). It must not be overlooked that the hyphæ of the fungus may grow through the pedicel into the lateral to which it is attached, and that it may continue down this until larger branches are reached; these may become girdled, and the whole branch in consequence be killed outright. This mycelium may persist for one or more seasons, and throughout the growing season give rise to conidia. This feature was very noticeable in 1915, and again during the past season, when laterals bearing mummies were commonly found to contain cankers.

Should the mummies fall to the ground they may for a time produce conidia, but in a short while the mycelium within them becomes darker in colour and more compacted, and forms sclerotia, which remain in a passive condition until the following season, when at blossoming-time they may give rise to apothecia. Should the mummies be buried more than 1 in. below the surface of the ground they are unable to produce apothecia; but such is the power of resistance of the contained sclerotia that mummies have been known to be buried for eight years and at the end of that time produce apothecia. The production of these bodies is governed by several factors. For example, weather conditions must be such that the fungus is stimulated into giving rise to them, and it would appear that a cold winter followed by a wet spring is most favourable for their development; they are produced *only during the blossoming-period*, and only when the mummy is lying on the ground or covered with about 1 in. or less of soil. That these facts have an important bearing on control will be seen later.

Apothecia* are saucer-shaped bodies borne on long stalks (Fig. 4), and are formed of closely woven hyphæ. The stalks grow from sclerotia embedded in the tissues of the mummies. The saucer-shaped portion is concave on its upper surface (Fig. 7), and the whole of this area is lined with asci (Fig. 8, *a*) and paraphyses (Fig. 8, *par*) arranged in a columnar mass, forming the hymenium or spore-bearing portion of the apothecium. The asci are long cylindrical sacs (Fig. 8, *a*), each containing eight colourless, one-celled ascospores (Fig. 8, *as*).

If conditions are humid the ascospores are ejected from the asci into the air, where they are caught and carried by air-currents to blossoms and young shoots in the vicinity. These may become infected and conidia be produced from the mycelium so developed, or the disease may be carried over the winter by mycelium embedded in the tissues of cankers formed the previous season, or by chlamydospores produced from mummies hanging on the tree.

ELIMINATION OF SOURCES OF INFECTION.

In order to enable brown-rot to be combated effectively it is necessary to destroy the sources of infection just described. Cutting out of cankered areas should present no difficulties, provided that

* An apothecium differs from a perithecium in being saucer-shaped and not flask-shaped, the hymenium being thus exposed as soon as the apothecium is mature. A drawing of a perithecium was contained in the article on black-spot published in last month's *Journal*.

pruning operations were carried out while the leaves were still on the trees, which would enable the dead shoots to be readily seen. Removal of infected fruits during the growing-period is advisable, in order to prevent shoot-infection. Destruction of mummies is a procedure that could also be carried out with ease, provided the mummies were those of peaches or apricots. In the case of cherries and plums the task would be a more difficult one owing to their small size. The only thing to do in such a case would be to remove the mummies from the trees during pruning, and plough them under prior to blossoming in the spring.

Another phase of control, and one commonly overlooked, consists in preventing contamination during picking, packing, and transit. The present system of handling fruit should be considerably modified, as at present fruits may become inoculated in many ways during picking and packing operations. The writer would suggest the following procedure, which may agree in general with the methods adopted by certain growers (that it is not a universal practice is obvious when many orchards are visited): Pick only those fruits which appear to be free from brown-rot lesions, and thus avoid contaminating healthy fruits with the hands or through contact with diseased ones. Pick into a box, or preferably a tin, instead of a picking-bag.* Once it has been filled place the tin out in the space between two rows of trees where it may be picked up and taken to the packing-shed. Contamination from the picking-bag is thus eliminated, the peaches stand less chance of being bruised, and a certain amount of time is saved. In the shed the fruits should be packed directly from the receptacles into which they were picked, and not dumped into a packing-bin, as is too commonly done. The writer has shown elsewhere that the second-hand case is a factor in transit infection, but if sterilization is carried out there is no reason why second-hand cases should not be used. At the end of the day the picking-tins should be sterilized, and stacked upside down until required.

Great care should be taken in the elimination, during picking, of all fruits infected with brown-rot; these should be left in the orchard, where they will be dealt with later. In packing, all fruits showing bruises or skin-injury of any kind should be rejected. These should be packed in separate cases, and where possible their sale should be limited to the nearest local market. It must be remembered that 75 per cent. of fruits in the market found to be infected with brown-rot show that infection has spread from skin-injury. All fruits intended for market should be wrapped in paper similar to that used for wrapping apples. This would prevent infection from external sources during transit, or from second-hand cases (thus rendering sterilization of these receptacles unnecessary), and would limit the spread of the disease within the case to those fruits which might develop brown-rot during transit. Moreover, wrapping would minimize skin-injuries and

* An excellent picking-tin is made as follows: Cut a side out of a benzine-tin, turning the edges down all round, with the short edges turned over *outside* the tin. At each end fasten a small wire handle to which, during picking, a broad strap passing around the shoulders is fastened with two spring clips.

would lessen bruising, as it is well known that wrapped fruits may be packed more compactly in the case.

CONTROL.

(By J. A. Campbell, Director of the Horticulture Division.)

It has been shown in the foregoing matter that brown-rot may be carried over in cankers formed on laterals and branches, and in mummies hanging on the trees and lying on the ground; furthermore, that infection is not confined to fruit hanging on the tree, but may occur during picking and packing operations, and even during transit, and subsequently in the market. As is well known, brown-rot is the most difficult of orchard diseases to combat, and it must be admitted that by spraying alone the disease will not be entirely held in check. This necessitates further action, particularly in the direction of minimizing infection by the destruction of mummies, cutting out of cankered shoots, and precautionary measures during harvesting and marketing. In short, successful control can be effective only when rigid orchard hygiene is carried out as a preliminary to spraying. If attention is paid to the cutting-out of all cankered shoots during pruning, to the destruction of all mummies, and to the elimination of infection during harvesting as previously set out, then it may be claimed that infection from brown-rot will be reduced to a minimum, if not entirely prevented.

Carry out pruning operations while the foliage is still on the trees, as at this time all cankers and dead shoots will be clearly seen. This does not necessitate any marked departure from ordinary orchard practice, as autumn pruning is often carried out at this time, notably in Central Otago.

Remove all mummies from the trees and from the ground and burn them or bury them deeply. Plough in the autumn, and dig under all portions beneath the trees not reached by the plough. Do not disturb the soil during blossoming, as it is at this period that ascospore-discharge occurs. As has been shown, apothecia are not formed if mummies are buried more than 1 in. below the surface. Thin heavily, and thus minimize the danger of infection at points of contact of the fruits.

During picking and packing handle the fruit as little as possible, cull all fruits showing skin-punctures, and be careful to throw out in the orchard any fruits showing signs of brown-rot. Wrap all fruits intended for sale, especially when the market is situated some distance from the orchard. Sterilize daily all picking-tins. It may be well asked whether infection would be prevented during transit by dipping the fruits in some fungicide, or by fumigation. It must be stated that numerous experiments along these lines have been carried out by the Horticulture Division, but so far without results that would justify our recommending this procedure.

Follow up the elimination of the sources of infection by spraying according to the following schedule. This will in large part eliminate infection by wind-borne or insect-borne spores which may be carried from adjoining orchards, and, furthermore, will prevent the production of conidia.

Spray Schedule for the Control of Brown-rot.

No.	Time of Application.	Spray.
1*	When buds begin to swell ..	5–4–50 bordeaux, or 1–15 lime-sulphur.
2	In early pink	1–50 lime-sulphur.
3	Petal-fall	1–120 lime-sulphur.
4	One month later	1–120 lime-sulphur.
5	When fruits are half-grown ..	1–120 lime-sulphur.
6	Just before fruits reach maturity..	1–120 lime-sulphur.

* This spray will also control leaf-curl.

Spray applications 1, 2, and 3 prevent blossom and shoot infection, and tend to stop the development of conidia which later may cause fruit-infection. Sprays 4, 5, and 6 provide developing fruits with an effective coating of fungicide, and thus tend to reduce fruit-infection. If weather conditions are abnormally wet at the time when the fruits are beginning to mature, the number of spray applications should be doubled.

To sterilize fruit-cases several methods of treatment are effective. Immerse cases for one minute in boiling water; or in copper-sulphate solution, 1–100; lime-sulphur solution, 1–50; or formalin solution, 1–40. The cases must be dry before any fruit is packed in them. Immerse tins for one minute in boiling water, lime-sulphur solution, or formalin solution. Do not treat tins with copper sulphate, as they will corrode.

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Gradings of Butter and Cheese.—During the twelve months ended July, 1922, 1,010,956 cwt. of butter and 1,275,796 cwt. of cheese was graded by the Dairy Division. As compared with the preceding twelvemonth, butter shows an increase of 46·26 per cent., and cheese 14·21 per cent. Converted into butterfat equivalent the combined figures show an increase of 32·57 per cent. in butterfat production.

BOYS' AND GIRLS' AGRICULTURAL CLUBS.

THE TARANAKI AND WANGANUI EDUCATION DISTRICT COMPETITIONS: SEASON 1921–22.

J. W. DEEM, Fields Instructor, Department of Agriculture.

IN the *Journal* for July, 1921, the writer gave an account of the south Taranaki agricultural club competitions, together with a brief history of their inauguration. During the past year the clubs in this part of the Dominion were extended, and now embrace north and central Taranaki, and the Brunswick, Wangaehu, and the Feilding districts. As previously the clubs were run under the auspices of the New Zealand Farmers' Union, assisted by officers of the Education and Agriculture Departments, the latter Department again providing seeds and manure free and issuing instructions for the guidance of competitors in the growing of their crops.

In north and south Taranaki the crops grown were mangolds and carrots, in central Taranaki swedes, and in the Brunswick, Wangaehu, and Feilding districts mangolds. Confirming the experience of last year, it was found that the swede competitions in central Taranaki were not very successful; the swede crop is too risky for children, and it should be replaced by something more reliable—a crop that will give competitors a fair run. In addition to the crop competitions, calf clubs were operated in south Taranaki. It was again found that the results achieved largely reflected the interest shown by the teachers and supervisors. Taking the competitions right through, the people interesting themselves in the work have reason to feel proud of the success achieved.

Altogether, forty-three schools in the Taranaki and eleven in the Wanganui Education District competed in the field-crop clubs, the figures being as follows: South Taranaki, 235 entries, of which 66 per cent. completed and had their crops judged; central Taranaki (swedes), 107 entries, 26 per cent. completed; north Taranaki, 210 entries, 53 per cent. completed; Brunswick, 22 entries, 82 per cent. completed; Wangaehu and Feilding, eighty-two entries, 72 per cent. completed. In the calf clubs eighteen schools competed with 207 entries, of which number 166, or 83 per cent., presented their calves for judging. Calf-judging was done in December, and field crops in April and May.

In addition to the judging in the field, displays of roots were made at the New Plymouth, Hawera, and Palmerston North winter shows, all three shows having classes for club members to compete in. At New Plymouth and Hawera the competition was keen, and a very fine collection of roots was brought together, these displays being quite a feature of the shows. Calves were also exhibited at the Egmont Agricultural and Pastoral Association's Show, at Hawera, in January last, special classes having been provided.